Pivot Academy: A Design Cycle and ICT Approach to Supporting Competency-Based STEM in Rwanda

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CCS Concepts

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ABSTRACT

This paper presents a design-based review of Pivot Academy, a one-week STEM and ICT infusion program for high school juniors in Rwanda. The goal of the program is to give students hands-on experience in applying the scientific design cycle, with the outcome of applying this new knowledge to designing and implementing their own STEM-based service projects. In order to achieve these goals, we spent one week training local university mentors in the Pivot Academy curriculum and several days training local high school teachers on ICT in the classroom. We successfully completed the Academy with over 150 girls and deployed a small research team to conduct follow-ups at the school and meet with government officials for future replicability initiatives.

1. INTRODUCTION

In line with making Rwanda a middle-class nation and developing a knowledge-based society [5, 6], the Ministry of Education saw the necessity to shift to a competency-based curriculum and address the shortage of appropriate skills in the Rwandan education system [1]. As part of this shift, the Rwanda Education Board and the Minister of Youth and ICT have paired together on a mission to increase digital literacy and use of ICT in the classroom [4]. In this paper, we describe Pivot Academy, a joint partnership between U.S. mentors and a Rwandan University to train secondary students in the scientific design cycle and to train high school STEM teachers to use ICT for enhanced hands-on learning.

The intervention comprised a one-week mentor training program, a two-day teacher training, and a one-week student academy. There were an additional four weeks of teacher, student, and classroom follow-up to see how well the intervention worked and what gaps remained. We present our intervention and findings in the form of design-based research [3] as further implementation of the academy is planned for next term.

We present our project in terms of design-based research because design experiments are set in the messy situations that characterize real-life learning. Our project takes place at a rural female boarding school in Rwanda. This school was chosen as a partner because of the willingness of the local administration and its connections to a U.S. based scholarship program. Since the project was in a pilot mode, we made little attempt to hold variables constant, but rather aimed to identify all the variables or characteristics of the situation that would impact the success and replication of the program. Our team went in with a well-defined plan and made adjustments as the project unrolled and circumstances changed. This paper is organized in five parts: goals and elements of the design, setting where implemented, description of the intervention, outcomes found, and lessons learned.

2. ACADEMY DESIGN

Our goals for Pivot Academy were to effectively communicate the importance of the design cycle and to start students on developing their own STEM-based service projects. We also wanted to identify any factors that would influence our ability to replicate this academy at other institutions.

2.1 Program Description

Pivot Academy works as a one week STEM and ICT infusion program for S5 students in Rwanda. The academy reinforces the Scientific Design Cycle through hands-on experiments in physics, biology, chemistry, and computing that are complementary to the Rwanda competency-based curriculum. In the academy, students experience a combination of hands-on activities, new technology, and personal mentoring from university mentors. Students use this experience to create group projects to carry out after Pivot Academy.

The Design Cycle, as pictured in Figure 1, is the central theme of Pivot Academy. It begins with the definition of a problem – what is wrong in the environment or community? Once the problem is defined, students should identify specific requirements for solving that problem, be they material, financial, or social. Even with material, however, there may be many ways of approaching the solution, so the next step for students is to brainstorm practical solutions. After deciding on a solution, students develop a prototype and test it. Once students have tested a solution, they will evaluate the results and share them with their peers for additional feedback. From here the design cycle repeats continuously

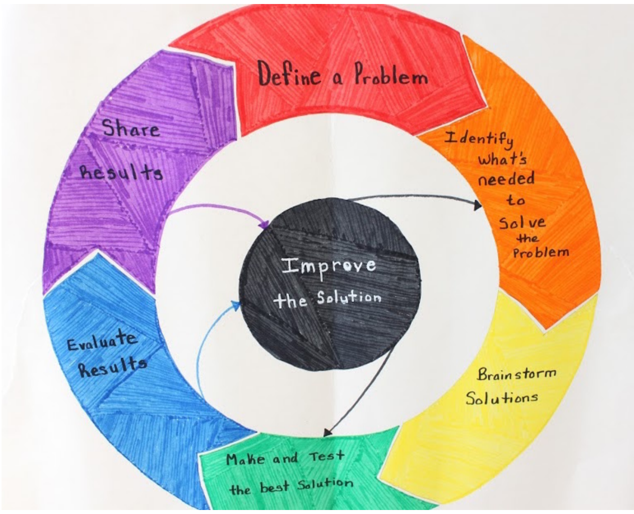

Figure 1: Design Cycle shows stages to scientific problem solving.

refining or improving the original solution.

Pivot Academy ends with students reflecting on their own passions and communities to design a long-term project that addresses an issue they identify around them. University mentors are responsible for guiding students through initial brainstorms, project requirements, and specifications. The academy prefaces this project with two central concepts: the SPARK, which is the students' central, driving passion in life, and FIRE, which is the problem that they see in their own communities. Mentors ask the students to reflect individually, then discuss with other students to form groups based on similar SPARKs or FIREs.

Students are encouraged to use the design cycle when formulating their specific project; Identifying the problem and brainstorming realistic solutions. They will then do research using tablets to determine the specific materials, equipment, and skills that they will need in order to complete their project. Though mentors can help with skill acquisition through additional workshops, Pivot Academy mentors are not responsible for funding student projects or buying materials. Instead, mentors can guide students on how to raise funds or gather what they need.

2.2 Materials

To reinforce the design cycle, students engage in several critical thinking activities, which require them to apply their STEM knowledge to practical situations. Each of the activities and content specific experiments are curated by U.S. content specialists who are nationally recognized high school STEM teachers. The hosting school provides each student with a notebook for journaling and reflecting on their days' activities. University mentors provide miscellaneous craft supplies for students to use when building solutions. For subject specific science experiments, mentors provide further specialized equipment, such as test tubes, thermometers, and anything else required by the lesson.

Pivot Academy distinguishes itself by equipping the school with android tablets for the academy and continued ICT-infused STEM lessons afterward. In order to utilize this technology however, the tablets must be prepared with all necessary lesson plans and apps because the intention after the academy is to use tablets in non-internet-connected classrooms. Tablets are donated with both compact solar chargers and practical multi-port chargers due to the potential inconsistency of power.

These resources – craft supplies, scientific tools, and especially tablets – represent a bulk of material costs but do not include the cost of presence at the school, travel, or any additional staff fees.

2.3 Collaboration Partners

The success of Pivot Academy depends on cooperation from several parties. First, the school administrators must approve time and classroom space for students to participate, particularly if the academy occurs during normal school hours. Second, teachers at the host school must work with the visiting mentors to adjust the lessons to the appropriate level for students. Visiting mentors will also introduce teachers to the tablets and discuss how to best use them in the classroom, including how to access academic material, find more material, and maintain tablets when passed through the hands of many students.

Before arriving at the host school, the Pivot Academy team recruits content specialists (physics, biology, chemistry, and computing) to develop activities for each subject. Depending on the size of the host school, X number of university mentors are also recruited to run the activities with students. Pivot Academy uses U.S.-based STEM majors to train local Rwanda university student counterparts. A week of preparation precedes the Academy, in which mentors from both countries meet each other and prepare the lessons for the intervention. Mentors pair up in teams of two (one U.S., one Rwanda) in order to rehearse and instruct the Rwandan mentor on how the academy runs, so that they may be better at extending the program to other local schools without direct intervention from the U.S. mentors. Furthermore, the Rwandan mentors will serve as better role models than the visiting mentors as they better understand the local school systems and cultural conventions.

3. IMPLEMENTATION SETTING

The two-week Pivot Academy intervention and four-week support program took place at a female boarding school in Byimana, Rwanda. The school serves 800 students in grades S1-S6, and once students reach S4 they must concentrate in one of three STEM tracks: Math, Computing, and Economics (MCE), Physics, Chemistry, and Biology (PCB), or Math, Chemistry, Biology (MCB). Rwandan schools are allowed to offer only one elective subject, in this case religion [2].

The school is fortunate as it has both science and computing laboratories (ICT lab) as well as a supportive administrative staff. Although students are only allowed to use the physics and chemistry laboratories during class time, one computing lab is available for use briefly after school and during breaks. Non-computing teachers will also use the ICT lab during breaks to access their email or Wi-Fi on personal laptops.

The computing lab has 42 computers which run a modern operating system. When the project started only 8 of the machines were wired for internet, but this number grew to about half as the project progressed. The computing lab also had Wi-Fi available that would reach into a nearby common room and the director of studies offices. The school however did not have admin servers or a consolidated way to control all of the computers so students would identify and change admin passwords, locking the ICT teacher out of the machines. It was common to reformat the computers.

Only ICT classes were taught in the computing lab. Non-MCE students rarely used the computers for research or studying for other classes.

4. IMPLEMENTATION DETAILS (PHASE 1)

4.1 Week 1: Preparations

In the week prior to Pivot Academy, mentors completed all planned activities to uncover and address probable pitfalls. As such, U.S. mentors partnered with Rwandan mentors not only to become acquainted with each other but to perform the tasks that would later be asked of the students. For this initial pilot, these activities included general engineering challenges such as building the tallest tower while hindered in some way (e.g. cannot talk, can use only non-dominate hand), designing a bag to for school or groceries, and creating a device to prevent an egg from breaking when dropped. On Day 3, there were also content-specific experiments introduced, including water filtration (chemistry), food dehydration (physics), food preservation (biology), and CS Unplugged/Mobile apps (computing). Mentors also discussed smaller tasks and lessons, affirming an understanding of the design cycle and the distinction of SPARK and FIRE in developing a long-term project.

The Pivot Academy team split into two groups in the second half of the week. Content specialists visited the school during class hours and discussed with the local teachers how the following week would proceed. The remaining mentors stayed behind to prepare the material resources for the major activities and reiterate over the lessons.

Few changes were made to the original design this week. A few activities adjusted to meet resource limitations: the salt-based dehydration project originally planned to have one kit for every 4 students, but would instead accommodate one group of 20 students per kit; the sand for the water filtration project was too dirty and therefore replaced by a less dirty substance (ash from the school kitchen). Otherwise, we stuck to schedule.

4.2 Week 2: Academy

Pivot Academy began on a Monday, completely replacing the regularly scheduled school week for the S5 students. This week was predetermined by the host school a year in advanced. S5 students broke off into teams of roughly 20 people by their concentrations. Mentor pairs were matched with teams based on student concentration and the subject-specific content the mentors were trained in the previous week (e.g. computer science, chemistry).

The primary goal of this week was to introduce students to the Design Cycle and enable them to apply it to their own special projects. As such, we introduced the cycle on the first day and practiced it on a few small projects, such as the Tower Building and Bag Design tasks. At the end of each day, we reflected as groups to discuss the application of the cycle throughout the day to reify it as a useful tool across many domains.

Another goal was to instill in these students specific scientific skills. Therefore, on Day 3, we circulated the teams through a series of workshops that aligned with their concentrations. MCE students, for example, experienced a gamut of offline computer science activities to introduce them to security, networks, and databases. They also used the tablets to design and prototype small apps. PCB and MCB students, on the other hand, learned about water filtration, food dehydration, and preservation, as these was more aligned to their studies.

Finally, we wanted to leave the students with ideas for long-term projects that would address problems they saw in their own community and provide them with the knowledge and resources to continue development on them. Students began the design cycle with the concepts of SPARK and FIRE that would help students introspect first and then partner with like-minded students. Students were allotted the final two days of the week to work on projects. First they brainstormed ideas and then met with their team mentors to discuss and revise before approval. By the end of the week, each of the 39 student teams had devised community projects to solve a problem, ranging from establishing a chemistry club to allow other schools to come in and use the lab space to constructing a web platform to allow parents, students, and teachers to communicate with each other as well as share issues with government.

We successfully implemented each activity that we planned; likewise, students successfully applied the design cycle and reflected on what they had learned. Although we had agreed on a precise schedule for when each activity would occur in the prior planning week, it was loosened to accommodate when students would show up 15 minutes early or late, or when it was discovered that lunch ran an hour longer than anticipated. Furthermore, one of the originally trained Rwanda mentors had to be absent at the beginning of the academy, so a new mentor was introduced during the first few days.

The biggest disruption was faulty communication about the technology at the school. The computer science content specialists were told that the main hall (where lessons were held) would be equipped with fiber internet to support the tablets, which led to the app-development portion of the curriculum, but this was not the case. Furthermore, though the computer lab had over 40 computers, only a few had internet. Because of this unexpected discrepancy, mentors were under extra stress the week of the academy to redesign the app development activity and find viable solutions.

4.3 Weeks 3-6: Follow-up

Rather than leaving the school unsupported with a lot of new technology and the students with large projects, the Pivot Academy team planned to leave two mentors/ researchers at the school for four weeks to continue helping the students and to educate teachers in how to use the donated tablets. In the four-week plan, the follow-up team would observe classrooms in the first week to understand how students worked. After that, they would help teachers introduce tablets into the classrooms and facilitate science activities. The team would also have weekly office hours where students could meet to discuss their project's progress.

During the week after Pivot Academy, the team observed S4, S5, and S6 students in their classrooms and talked briefly with teachers about the concerns they had over tablets. During the classroom observations, the team discovered that the students were entering final exams in the next week. As such, there would be no more classes to which they could introduce tablets and students would lose much of the time planned for project development.

Even with the adjusted plans, however, their were additional roadblocks from a myriad of sources. During week 4, the follow-up team was pulled away to attend to complications in visa paperwork at the immigration office, preventing them from doing any work at the school. Furthermore, upon returning to the school the follow-up team was not able to clean-up and apply proper security software to enough computers or get students to agree to a period of time where they could hold a skills training workshop for web design.

After this, the mentors split their attention in two ways. One mentor remained in Byimana to continue efforts on project mentoring and small workshops for project management and online services like Google Drive. The Byimana mentor also lead a series of small, impromptu digital literacy workshops with nuns from a convent neighboring the school. The other mentor returned to the capitol, Kigali, to meet with and pitch Pivot Academy to various government officials. The results of these meetings can be found in Section 5.4.

By the time final exams ended, there were only a few days left before the students returned to their home villages for end of term break. In this time, we decided to focus on preparing teachers with the new technology and preparing the local Rwanda mentors to take over the program. Workshops were held at the school to introduce teachers to tablets and to brainstorm ways to use them in class, all while collecting feedback for how they would like to see the tablets improved. Both mentors met with each student group one last time to officially document what they needed for their projects and how the students would determine if their project was successful. With this information, the U.S. based follow-up team held one last workshop with a core group of the Rwandan mentors to discuss the projects and run through one of the planned workshops to ensure that the project could continue at the Byimana school in the following term.

5. OUTCOMES FOUND

In this section, we discuss the individual perspectives from each of the stakeholder groups pertaining to the implementation, outcomes, and success of the program.

5.1 Student Perspectives

One of the goals of Pivot Academy was to invigorate the girls' attitudes towards STEM and give them the experience of hands-on experimentation. During the course of the first week we were able to see students open up and become more vocal about their opinions and hypotheses. When talking with the students, none of the girls had done anything like the egg drop or tower building activity before. The only activity students had seen something similar to was bag design, as many of the students have taken a sewing class.

Students also enjoyed conducting the science and computing activities on day 3. The students felt like they learned a lot and could use what they learned for later projects. The students did, however, have their concerns. One of the S5 students said, "If we check on our fruits after school, then the other students will know we have food there and steal it." This student was referring to the food preservation experiment where food could stay refrigerated for short periods of time in clay zeer pots.

Students had fun during the CS unplugged activities and the ICT teacher referred to several of these activities in the coming weeks. However, the students had mixed attitudes towards the mobile app workshop. Students were very satisfied with the content and being able to deploy apps to the tablets, but when it came time for personal projects, the students wanted to develop apps or websites that were compatible with feature phones since those were more widely used in the country. During the time of Pivot Academy, mobile phone penetration was at 78% and smart-phone penetration was 17%. Rwanda joined the Smart Africa Alliance in 2014, increasing priority on making data availability.

Feedback on mentoring sessions was all positive for technology centered projects, but non-ICT feedback was more complex. The students who proposed ICT-type projects felt confident in the mentors ability to teach them web-design and project specific necessities for their apps. The students also felt creative in being able to come up with the design of their projects and get feedback from their peers. Other students had project ideas such as establishing internet cafes in their local village, building orphanages for street kids, and building water filtration systems for the school and nearby community. These students felt less confident in the mentor's ability to help realize their project. Mentors guided students in turning these large scale projects into project proposals with budget and resource information so that if funding was available, their plans could one day happen.

5.2 Mentor Perspectives

5.2.1 Rwanda Mentors

All of the Rwandan mentors were excited to participate in this project. One of the mentors actually attended this school, so it brought her great pride to give back to her community. For other mentors this was their first time to a place like this; outside of Kigali or another major city or tourist destination. Similar to the Byimana students, this was the first time any of the mentors had done an activity like tower building or egg drop. When asked what do they think the egg drop activity was about, one mentor replied that it's about protecting the egg and finding ways to carry the egg home from the store. The mentors didn't understand at first that the activity was actually about the design cycle and learning to think in different ways and approaching a problem from different angles.

Feedback during Pivot Academy centered around a feeling of influence and being an important part of the Byimana students' education. One mentor captured the feeling as, "I think we showed them we are good role models. We are in university. Maybe they can go to university too." This sentiment was echoed by the U.S. mentors, "We are outsiders here, we barely speak their language. The students are really looking up to the Rwanda mentors."

When asked if they will do a program like this again, three of the mentors signed up immediately to continue working with the school in the upcoming term. Another mentor said they will not be coming back, but maybe they will help at a school with boys.

5.2.2 U.S. Mentors

The U.S. mentors were also eager to be a part of the program. The mentors were fully accepting of location-based issues such as power outages and infrequent access to water and electricity. At least four of the U.S. mentors had run either summer camps or after school programs before and were very familiar with the types of activities conducted. After working with the Rwanda mentors and training them in the STEM activities, the U.S. mentors felt confident in their ability to carry out Pivot Academy.

The U.S. mentors, however, having experience in STEM camps and similar outreach activities, were more concerned with the organization of the program. Not all activities were timed out well and the mentors did not know which part of the school year the students were in, so they were not sure which parts of the curriculum they should cater activities towards. Additionally, the U.S. mentors were all STEM and ICT majors, the Rwanda mentors were business administration and health administration service majors, so the U.S. mentors felt they had to train the Rwanda mentors in computing basics before they could teach the S5 lessons.

During the Pivot Academy follow-up, the mentors wanted to have a better idea going into the program about what project types students would be creating. Since each group was mentored by different pairs, the information transmitted to the follow-up team came in many different forms and did not fully encapsulate the student projects. Mentors were surprised when they heard about several of the large-scale projects mentioned earlier.

5.3 Teacher Perspectives

5.3.1 Byimana Teachers

The teachers at Byimana were pleased overall with the curriculum materials and tools that we provided to the school. Each teacher training session was attended by 8-12 teachers. The training primarily served teachers involved in the Pivot Academy program, but teachers from other subjects would also attend.

Mentors found that teachers who were already tech-savvy were very eager to work with the tablets for classroom use and sharing new content with students. These teachers attended some of the training, but otherwise felt they were already prepared to use the tablets and materials in their classroom. For other teachers who were not tech-savvy, they appreciated having time to explore the tablets and learn how to operate them. Once they became familiar with the medium, they were eager to discuss ways in which tablets can be used in the classroom.

Although many teachers, including those from language and religious studies, came to the workshops to learn about ICT in the classroom, one biology teacher was not interested in using the tablets. She already had a lab with equipment, and felt the tablets would serve as a distraction, plus she would have to learn a cumbersome new tool.

5.3.2 Content Specialists

Each content specialist felt that Pivot Academy was successful. Some felt they had difficulties explaining certain concepts because of the language barrier, but with the help of the local Rwandan university mentors they were able to express the lessons. The chemistry specialist stated, "When I would ask the girls general questions they would stare blankly at me, but once we were talking about formulas and equations they lit right up and would know the answer." The specialists were also pleased with how the mentors would help throughout the program; from one of the specialists: "I thought the academy part went well, but I believe a lot of that is due to our team of U.S. engineering students. Things were not as we were told before coming here, but somehow they managed to make it work."

5.4 Rwanda Government Perspectives

As part of the follow-up to Pivot Academy, there were several meetings with government officials in the Ministry of Education to discuss their opinions of the project and how potential partnerships would work in the future. The first meeting was with person1, a program coordinator from an ICT camp for villagers in rural areas. Person1 was very eager to work with the academy on bringing technology into Rwanda for schools and outreach programs. She also put the team in contact with other individuals who would be interested in supporting the program.

The second meeting was with an official from the Rwanda Education Board. She was much more critical of the program due to her knowledge of e-learning programs and past experience with failed NGOs. The main concerns were with the tablets, as the material could be downloaded by local teachers without the need of Pivot Academy. Additionally, she wanted to know precise scalability plans: "clearly you don't want to go to every school in Rwanda. Your first experiment was at a school that already had power and internet. Do you only want to help schools that already have resources?" Her perspective was that this program was still young and not as documented as she would have liked. Although disheartening, it gave much needed guidance for entering into new meetings.

The next set of meetings were with senior technologists in the Ministry of Youth and ICT. They were excited by the availability of offline curriculum materials that were aligned to the Rwanda competency-based learning goals. The MYICT officials also wanted to partner by Pivot Academy including additional lessons on digital literacy provided by the MYICT office. Further partnerships also included packaging the tablet materials for laptops and computers to help decrease the cost of tablets into schools that already have technology, in addition to hosting teacher training programs in ICT content and pedagogy. Outcomes from this meeting included adding Pivot Academy to the ICT Exhibition that would be circulating around Rwanda to showcase how ICT can be incorporated into STEM learning.

6. LESSONS LEARNED

We have learned many things in our foray into STEM camps for developing countries, primarily pertaining to people and communications.

Our first major lesson was that even though we may have many verbal confirmations from coordinators on the ground, we won't know what we are dealing with until we get there. By Skype calls and email it was confirmed months in advance that the school had two computer labs and high quality Wi-Fi available to connect tablets to and to run an app development workshop. After arriving in person, however, it was discovered that low-level Wi-Fi was only available in the computer lab and a small part of the main hall where the academy would be taking place. The academy was invited to use the computing labs that had newly updated equipment, but only 8 out of 42 computers had internet (with no Wi-Fi capability). By taking too much assurance in wordof-mouth confirmations, academy mentors hectically tried to salvage the entrepreneurship and app programming lessons and continually had to clarify exactly what kind of resources were available.

This lesson also extends to organizing student availability. For example, only after arriving was it discovered that students were in their second-to-last week in the term, with finals following thereafter. Furthermore, computing mentors had little insight into how much the students knew already. The competency-based learning curriculum that was consulted stated that S5 students should be learning about databases and network administration and have already known basic programming and web skills. However, when interacting with the students, it was clear that their knowledge of computing was oriented more around hardware than practical hands-on computing. These gaps in student knowledge are partly explained by the school's recent switch to the new curriculum.

As for project tutelage, there was little in the way of project accountability at the end of Pivot Academy. The initial schedule planned for the follow-up team to host office hours and help guide students with their projects for four weeks. However, due to the students' lack of project development experience and a lack of consistent environment for office hours, mentors needed to host much larger workshops to teach students general research and development skills. Unfortunately, students only had one week until exams started after the academy was over, so students did not want to have workshops while they were preparing for or taking exams. This generated a lot of pressure on the mentoring team to host several workshops with highly concentrated information on different skills, some of which were unfamiliar to part of the team. We believe if mentors were informed about student skills and timing in the academic year prior to arriving, they could be better prepared for handling student project mentoring.

The remaining two lessons learned were centered in the Rwandan culture. The local Rwandans were very pleased to have U.S. mentors helping and never wanted to disappoint, but this led to many of the communication issues. As for the Wi-Fi specs highlighted earlier, the Rwandan coordinator did not want to tell the team "no" or that he "disagreed" with their opinion as this was seen as being very rude. In a different situation, an IT person was asked if they had a voltage meter available. He replied yes and offered to get it but then disappeared for the rest of the day rather than telling the team no and disappointing them. After interacting with the people there more, it was realized that the U.S. mentors were still relying on their own cultural conventions to do work, and this was not sufficient to collaborate well. some of this was anticipated before, motivating the choice to cooperate with Rwandan university mentors to teach the students, but there was still much to learn.

When working with the government officials in Rwanda, it was realized that they come with many different experiences. One official was highly critical of Pivot Academy, as she has seen many failed education projects in the country before. Consequently, as mentioned in section 5.4, the team needed to go in with much more paperwork and documentation about their plan so that the official could thoroughly read and review the project before agreeing to any partnerships or future collaboration. When working with Officials in the Ministry of Youth and ICT, who were just starting a new initiative, they were much more open about working with the academy and brainstorming many different collaboration opportunities.

In retrospect, some of these lessons were blind-spots when planning for Pivot Academy and are variables we can account for in future iterations of the program. Additionally, a full-time in-country coordinator has been hired to be fully attentive to the working and progressions of Pivot Academy.

7. CONCLUSIONS

We initiated Pivot Academy, a one-week STEM and ICT infusion program for secondary students in Rwanda, with the goal of giving students hands-on experience with the scientific design cycle and reinforcing important learning objectives. In order to achieve this goal, we spent one week training local university mentors in the Pivot Academy curriculum and several days training local high school teachers on ICT in the classroom. At the end of the academy, students were able to apply this new experience towards designing and implementing their own STEM-based service projects. We successfully completed the Academy with over 150 high school girls and deployed a small research team to conduct follow-ups with the students and teachers, as well as meet with government officials for future replications.

Through our implementation and follow-up efforts we have gleaned vital information on the stakeholders perspectives as well as infrastructure and community support that will be needed for future iterations.

8. ACKNOWLEDGMENTS

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